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Applicant: Minimax GmbH
23843 Bad Oldesloe, DE

Inventor: Dittmer, Hauke, Dipl.Ing.
23769 Puttgarden, DE

Processes and device for fire detection with gas sensors

This invention involves a process and a device for fire detection of open and concealed fires by means of electro-chemical gas sensors.

Known fire detection systems, which work following the principle of gas sensor technology, use special semiconductor components for the deterction of gases, which must be calculated with a high precision with respect to interfering gases and humidity, however. These disadvantages can be avoided through the use of specifically designed electro-chemical gas sensors of various constructions. The electro-chemical gas sensors that would be used in the present invention also detect various types of gases which are characteristic of the fire formation and the fire responder can be integrated, in a preferred version, together with other sensor types (ionization smoke responder, flame responder).

Exact information about the course of a fire permits me [*to make*] an accordingly logical interpretation of the various sensor signals.

Description

This invention involves a process and a device for the early diagnosis and for the complex evaluation of fires, such as open and concealed fires or carbonizing fires (specifically also from rubble-like or otherwise stored materials) yet in its formative phase.

In buildings, public facilities, industrial installations and warehouses, but also in residences, millions of damages are created annually through the outbreak of fires. Such fires occur frequently through the inattentiveness of people, carelessness in the contact with combustible materials or technical defects, such as defective electric conductors.

The transport of initial ignition, such as glowing particles or spark, onto combustible materials, and often leads to ignition of other combustible material in their surroundings.

Smouldering fires usually occur at a single location or are scattered with several initial ignitions at several locations.

As a rule, a longer period is necessary for a carbonizing or smouldering fire to start an open fire.

With the classic fire alarm systems, based on flame or smoke responders [*Brandmelder = fire reporter, responder, announcer*] , such smouldering fires are not detected in their formative phase.

Only through the appearance of flames or smoke, are fire reports received by these sensor systems which can cause the sounding of an alarm and an extinguishing device to be activated.

Valuable time is lost, that could have been used advantageously for an early diagnosis of a fire for fire fighting and for persons rescue, whereby one would expect also considerably less damage with the earlier fire-fighting.

It is generally known that the first indications of the formation of a fire is frequently the emission of gases, specifically gases from material-dependent pyrolysis.

During this pyrolysis process in a carbonizing fire, material-specific, gaseous products are set free in various concentrations,

Here, carbon monoxide (CO), hydrogen (H_2), methane (CH_4) as well as long-chain saturated and unsaturated hydrocarbons and sulfur compounds are important.

In the course of the further fire development, and as well at increasing temperature, the emission of products of a complete combustion increases, such as of CO_2 and H_2O.

The gases appearing in the formative phase of a fire, at the moment in low concentrations, are detected early by suitable gas detectors. People are quickly warned and suitable fire-fighting agents are introduced.

An application of gas sensors for extinguishing fires, specifically concealed carbonizing fires, is known from the patent literature.

Thus, in EP 0 608 483 A1 is disclosed a process and a device to the investigation of fire and explosion dangers of open or concealed fires, by which the gas development from materials is determined and evaluated by the principal resistance performance of at least two semiconductor gas sensors (preferentially SnO_2 sensors) while reacting to the gases.

Different resistance performance of the sensors can be obtained through different operation temperatures and by the use of different physical procedures.

Alternatively, in principle, resistance sensors can detect gases characteristic of a dangerous situation through several semiconductors with different resistance properties.

With the appearance of a dangerous situation with gas formation, an alarm release takes place in those cases in which the measured values detected by the sensors exceed a critical range or from previously saved critical samples.

In the center of this known invention, an early detection of gases occurs through semiconductor gas sensors, specifically for the fire detection in dust filled spaces.

However, applications known until now of the use of semiconductor sensors for gas deterction with carbonizing fires have the disadvantage that humidity in different concentrations and a high interference from disturbing gases have a significant influence on the reliability of the measured results and they cannot be calculated with a constant sensitivity. Furthermore, the number of types of gases detectable by means of semiconductor sensors is quite restricted. Semiconductor sensors have a very high power input in order to reach their over 100° operation temperatures. Moreover, the catalyst layer of semiconductor sensors is disintegrated by the presence of some materials, like silicone, lead, phosphate and sulfur compounds, so that the function is no longer guaranteed. Other compounds, like hydrogen sulfide and halogenated hydrocarbons, are absorbed by the catalyst of the semiconductor sensors which leads to a considerable reduction in sensitivity.

The existing fire dangers in many areas of industry, residential, and public facilities are of mostly different types and make necessary a flexible type of danger-adjusted sensory concept.

The investigation of the fire-specific gases, gas concentrations and their temporal trend are of great importance for an early warning system in fire protection.

Pyrolysis gases, quickly emergent in the formative phase of a fire, often are toxic even in low concentrations and form a primary danger for human beings and animals.

Therefore, underlying the present invention, the goal is to create a process and a device, which yields reliable gas concentration measurements which allows an early and selective detection of the gases characteristic of fire formation and their use in areas with very different materials and/or dangers. This goal is resolved through the features stated in the characteristic part of the first claim.

Preferred designs of the invention are stated in the dependent claims.

The characteristic gases (pyrolysis gas) produced from an emerging fire and the fire development, is detected by one or more fire responders with one or more electro-chemical gas sensors, whereby several electro-chemical gas sensors of the same or different construction are used for the detection of the same or different gas types.

Also by different suitable controls of the electro-chemical sensors, different gas types within fixed limits can be detected.

Thus, electro-chemical gas sensors determine gaseous materials if they enter into reactions in an electro-chemical cell or influence the reactions occurring in the cell.

Electro-chemical cells consist of at least two electro-chemical half cells. Further, a half cell consists of one electrolyte and one electrode.

The measurement of toxic gases takes place in so-called three electrode systems, with working, reference, and counter electrodes, which are conductingly interconnected together through an electrolyte.

Thus, a gas to be detected reaches the electrolyte through a hydrophobic diffusion capillary from the working electrode, for example.

The electrode possesses a gas-specific electro-catalytic layer. If traces of the to be detected gas are present, a three phase reaction occurs whereby the gas component is reacted.

At the counter electrode of the cell, the corresponding counter-reaction takes place.

Through variation of the electro-catalytic layer of the electrode, suitable selectivity can be achieved for the deterction of various gas types.

In the invented device, the fire responder would use one or more different electro-chemical sensors (measuring cells) for the determination of toxic gases and oxygen.

Therefore, one or more same or different electro-chemical gas sensors are integrated into a fire responder and connected with a micro controller for the interpretation of the sensor signals.

Fire responders are available with electro-chemical sensors that detect selectively even the lowest gas concentrations to the ppm area.

A preferred version of the invention consists of the additional arrangement of one or more semiconductor gas sensors for fire detection. These can be integrated into a fire responder together with the electro-chemical sensors or also arranged separately.

Another to advantage design of the invention consists of the additional arrangement of one or more temperature sensors, which are also integrated in fire responder or can be arranged in its direct proximity.

With help of the temperature values determined in the direct surroundings of the fire responder and one in its micro controllers or an external central computer using intelligent control logic (software), the temperature influences on it or on the electro-chemical sensors of the fire responder can be compensated for.

Beside the detection of the gases characteristic of fire formation through fire responder with electro-chemical sensors, also the determination and interpretation of additional fire characteristics falls within the area of this invention.

The additional arrangement of suitable sensors, such as ionization, and refraction, as well as light transmission sensors, temperature sensors or radiation sensors for IR or UV-irradiation, enables one to determine additional fire characteristics and to also process current technical data. It is equivalent whether the fire responder (sensor array) are integrated with these sensors with the electro-chemical sensors together or whether they are arranged separately.

Through the detection of one or more gas component distinctive of the fire formation by electro-chemical sensors allows one to compensate for determined, variably adjustable disturbing factors from industrial surroundings, as for example, most often from the degassing from materials or in the domestic area from smoking or cooking.

The fire characteristics detected by the electro-chemical – and the other sensor elements are digitized and are stored in a memory.

Storage and calculation (micro controllers or microprocessor) can be done in the fire responder and/or also in the computer of a central fire responder.

In this case, in one or more memories, the trend of the sensor signals data can be followed and an automated zero point extension or sensitivity adaptation implemented.

By the temporal consideration of the concentration trend of one or more gases and their derivation as well as also the temporal consideration of the smoke aerosol density and the temperature rise and their comparison with the model tables or algorithms produced previously in fire experiments, a certain early identification of a fire is possible.

The data processing of all of the fire characteristics determined and the concentration trends of the gases then presents a complete picture of the current course of the fire.

A particular advantage of the invention consists of the possibility, through the choice of suitable sensors coupled with a computer, to produce a fire responder which gives early alarms and transmits valuable information as to the type and the state of the fire.

Thereby, the fire responder is equipped with corresponding means of detection for the indication of the measured gas concentration.

Preferably, LC-displays can be used here.

By the integration of different sensor types, besides gas concentrations, other gases and also other fire characteristics can be shown by the display of the fire responder. For that, a corresponding method of selection is shown.

The invented proceeding makes possible the targeted introduction of countermeasures possible, as for example the usage of effective means for extinguishing or the warning of people in the danger area before the toxic amount of identified fire gases.

In contrast to electro-chemical fire responders, a working fire responder following the refraction principle leads to false alarms because of contamination of the measuring space.

Ionization responders have a very high sensitivity and react to visible and invisible aerosols, so that faulty alarms can also occur here.

Through a coupling of one or more suitable gas sensor, the sensitivity of the sensors to smoke can be controlled and the false alarm rate is lowered.

In another preferred design of the invention, the connection and interpretation of the different sensor signals and the investigation of the degree of danger takes place with an expert system and/or a fuzzy logic. The expert system or the fuzzy logic is implemented in software in the micro controller of the fire responder or a centralized/decentralized computer.

This invention will now be explained in more detail on the basis of a drawing in an example of implementation.

Figure 1 shows a schematic representation of the invented device for fire detection with a single fire responder.

This invented device displayed in **Figure 1** for fire detection essentially consists of one

or more fire responders **8**, which are equipped with one or more sensors **1-5**, a micro controller **6** and a data memory **7** whereby at lease one sensor of the fire responder is formed as an electro-chemical gas sensor.

The electro-chemical gas sensor **1** integrated into this fire responder **8** is designed for the detection of carbon monoxide (CO) and possesses an effective range of approximately 300 ppm with a resolution of 0.5 ppm. A second electro-chemical gas sensor **2**, which is integrated into the fire responder **8**, serves with an effective range for the detection of hydrogen cyanide (HCN) of 50 ppm and a resolution of 0.5 ppm. It is used specifically for the detection of the toxicity of plastic fires.

A semiconductor gas sensor **3** is especially good for combustible gas air mixtures and hydrocarbons (C_xH_y). Because of the very low detection limits, semiconductor gas sensors are very well suitable for use in explosion dangerous zones.

Likewise, integrated into this fire responder **8**, are a temperature sensor **4**,and a smoke gas and/or radiation sensor **5**. The temperature sensor **4** serves for the compensation of the temperature behavior of the other sensors **1 to 3** on the one hand and yields temperature measured values of the current fire events on the other hand. The smoke gas and/or radiation sensor **5** yields additional valuable information particularly in the more advanced fire phase of the fire events.

The sensors **1 to 5** are connected by an A/D transducer with a micro controller **6** and a data memory **7**.

The fire responder **8** is either equipped with a display **10** for the indication of fire characteristics or other relevant information of the fire, or this information is transmitted over a central fire responder **9** to a display.

The extinguishing device, not displayed, is connected centrally over the central fire responder **9** or directly with the fire responders **8** connected through an alarm line. The link between the fire responders installed in the supervision area **8** and the central fire responder **9** takes place here in 2-conductor technology.

Measuring data is transferred continuously by means of a standardized 4 - 20 mA interface. Alternatively, up to one hundred fire responders **8** can be operated on one fire alarm line.

The fire responder **8** supervises extensive security functions, such as sensor control and voltage and operation supervision. The sensor calibration takes place through an attached device for menu-driven one-man calibration or it occurs through an automatic, electronic calibration.

The fire responder **8** is contained either in a synthetic material enclosing housing for interior areas or in a robust commercial housing that is suitable also for exterior usage.

The components of the invented device for fire detection operate together procedurally as follows.

In the case of fire, gases (pyrolysis gas, smoldering gases) form first from the involved materials. This happens long before smoke aerosols appear or a temperature increase can be detected by means of temperature sensor **4**.

Moreover these gases have molecular structures and distributions which on the basis of their lower weight, move faster in space relative to smoke aerosols.

The carbon monoxide, usually the first to appear in this formative phase of the fire, is therefore detected early by the electro-chemical gas sensor **1**.

The sensor signals of the sensors **1 to 5** are collected continuously or at adjustable time intervals via the analog-digital transducer, evaluated by the micro controller **6** and written into the data memory **7**.

On the basis of the data in the data memory **7**, the slowly changing sensor signals that are not caused by a fire, which, for example, are caused by sensor changes or environmental influences, are compensated for.

The carbon monoxide concentration determined in the surroundings of the fire responder **8** by means of the electro-chemical gas sensor **1** leads to the triggering of an alarm when exceeding a previously fixed limiting value as well as a concentration increase rate.

Limiting values and concentration increase rates are determined in accordance with the local characteristics of the monitored area and the type of the fire dangers, and stored in the data memory **7** of the micro controller **6**.

The alarm is further transmitted to the central fire responder **9**, evaluated and displayed. According to implementation and interpretation of this or the alarm programs in the computer unit of the central fire responder **9**, the extinguishing device, which is not displayed, is immediately, or after interpretation of additional fire responder data, activated.

Before activation of the extinguishing device, acoustic and/or optical warnings can also be produced. Endangered people in the monitored area have the possibility of moving away from the hazard zone in time.

With the invented combination of electro-chemical gas sensors of different construction **1, 2** and/or with gas sensor **3** working following another (**3**) measuring principle, additional information can be determined about the fire and its environment conditions, such as, for example, the temperature rise, the smoke evolution and the concentration increase of poisonous gases.

Thus, hydrogen cyanide produced by the combustion of synthetic materials is detected in the electro-chemical gas sensor **2** and its concentration increase evaluated with the help of the micro controller **6** or in the central fire responder **9**.

With the further development of the fire and increasing temperatures, the emission of products of the complete combustion, such as of CO_2 and H_2O, increases.

Such combustion products and/or the concentration increase of combustible gases, specifically hydrocarbons, is detected reliably by one or more semiconductor gas sensors **3** integrated with the fire responder.

The detection of additional types of gases and their temporal concentration trend yields valuable information about the type of fire and the fire development, so that an intelligent evaluation of the gas sensor signals, permitting the selection of fire-fighting by suitable extinguishing methods or other selective fire-fighting measures.

The signal from the temperature sensor **4** transmits the current temperature trend in the recording area of the fire responder **8** and is used for the compensation of the temperature influence on the gas sensors **1 to 3**.

An integration of smoke gas sensors **5** (ionization smoke sensors) and/or radiation sensors **5** (optical radiation sensors, IR, UV) from which fire responder **8** yields additional information about the fire development, specifically in a more advanced phase of the fire development.

The micro controller **6** processes essentially all of the signals coming from sensors **1 to 5**, especially also the sensor signals of the conventional fire characteristics, such as heat (**4**), smoke (**5**) as well as infra-red and ultraviolet radiation (**5**) and couples these for a complex function of the state of the fire development.

A more reliable detection and compensation of interfering factors, that can misrepresent a fire formation, makes the intelligent interpretation of the sensor data descendant from several sources possible so that faulty alarms are most completely excluded.

Thus, an early and secure control of the extinguishing device is possible.

Another use of the micro controller **6** is the supervision, operation and calibration of the sensors **1 to 5** and their maintenance. The corresponding values are also stored in the data memory **7**.

The control of the LC-displays of the fire responder **8** and/or a decentralized or central indication device **10** as well as warning messages on the central fire responder **9** for the improvement of the protection of the people, also occurs through the micro controller **6**. Thus, the micro controller **6** can be built, in that case, also as a programmable logical unit or as a microprocessor.

Also falling within the area of this invention [*is the case where*] the different sensors **1 to 5** are not integrated into a fire responder **8** but can be arranged separately from each other.

The signal storage and interpretation then takes place in a central fire responder or in decentralized facilities.

Significant advantages of this invention consist of the possibility of an early fire detection what leads to a reduction of the fire and the damages of real property from extinguishing liquids and averting danger to people.

The fire responder used based on electro-chemical sensors and the further additional arrangement of sensors operating following various measuring principles as well as their common signal interpretation and intelligent processing permits not only the selection of suitable extinguishing materials but also yields information about the properties of the burning materials by the gas concentrations of different gases etc.
In combination with fuzzy logic and a corresponding data bank, additional information is available for the use of the fire brigade, as for example, the suggested type of safety mask or the expected heat development.

The invention allows a more exact evaluation of the actual fire events.

Reference designation list

1 - Electro-chemical gas sensor for CO-detection
2 - Electro-chemical gas sensor for HCN-detection
3 - Semiconductor gas sensor for C_xH_y-detection (detection of combustible gases)
4 - Temperature sensor
5 - Smoke gas sensor/radiation sensor (ionization, light diffusion/optical radiation sensor,
6 - Microcontroller/microprocessor
7 - Data memory
8 - Fire responder

9 - Central fire responder (extinguishing device)
10 - Display, indication device of fire characteristics, information about the fire and warning messages

Patent claims

1.
Processes for recognizing open or concealed fires or fire nests in industrial installations, public facilities as well as in residences,
thereby characterized
that the gases evolving from an emerging fire are detected and the fire development characterized by one or more fire responders (**8**) with one or more electro-chemical gas sensors (**1, 2**), whereby several electro-chemical gas sensors (**1, 2**) of the same or different construction are used for the detection of the same or different gas types.

2.
Processes following claim 1 **thereby characterized** that the fire formation and the fire development characteristic are detected with different gas types with the help of gas sensors based on different measuring principles, specifically electro-chemical and semiconductor gas sensors (**3**).

3.
Processes following claim 1 or 2, **thereby characterized** that the temperature influences on one or more the gas sensors (**1, 2, 3**) is compensated by temperature measurements in the direct proximity of the gas sensors by an appropriate temperature sensor (**4**).

4.
Processes following one or more of the claims 1 to 3, **thereby characterized** that in addition to the measurement of gas concentrations specific for the fire-material, also the fire formation and the characteristic fire properties of the fire development are measured and the temperature trend and the radiation values, specifically from the infra-red and the ultraviolet area, specifically of the smoke, are evaluated.

5.
Processes following one or more of the preceding claims, **thereby characterized** that one or more of the characteristic gas components from the formative phase and/or the course of a fire is detected for a time span (t), digitized and saved,

whereby the storage and processing of the signals by one or more fire responders (**8**), which are interconnected with at least one micro controller (**6**) with storage device (**7**) and/or with a decentralized or centralized computer,

resulting in the investigation and evaluation of the danger situation in dependence on the gas concentration and from the temporal increase of the gas concentration.

6.
Processes following claim 5, **thereby characterized**, that the background concentration of the gas typical for the fire formation is determined and the fire development in preset time intervals and the sensitivity of the gas sensors (**1, 2, 3**) is accordingly followed.

7.
Processes following claim 6, **thereby characterized**, that the interpretation of all sensor signals takes place with an electronic computer unit, which is centrally connected specifically to one or more fire responders (**8**) or is decentralized and the investigation of the degree of danger in a fire-typical coupling of the sensor signals takes place with an expert system (**9**) and/or a fuzzy logic evaluation and/or through comparison with model tables or saved algorithms.

8.
Processes following claim 7, **thereby characterized**, that the determined and evaluated information and/or characteristics concerning the fire, such as fire type, the fire characteristic gas types, type of the materials obtained in fire and additional references of the choice of extinguishing agent and/or to endangering existing persons, etc. is shown and/or saved and conveyed to a constantly monitored site, such as a control location of a fire brigade by means of display (**10**).

9.
Device to the early recognition of open or concealed fires or fire nests in industrial installations, public facilities as well as in residences, comprising one or more fire responders (**8**), comprising at least one fire responder (**8**) with one or more gas sensors (**1, 2, 3**), **thereby characterized** that one or more of the gas sensors is made as electro-chemical gas sensors (**1, 2**) with the same or different construction, whereby different characterizing gas types of the fire formation and the fire development are detectable.

10.
Device following claim 9, **thereby characterized**, that gas sensors, which operate following different measuring principles, are used, specifically electro-chemical gas sensors (**1.2**) and semiconductor gas sensors (**3**).

11.
Device following claim 9 or 10, **thereby characterized** that, one or more gas sensors of the same or different construction are integrated into a fire responder (**8**), in order to detect various of the characteristic fire gas types.

12.
Device following claim 11, **thereby characterized** that in addition to the gas sensors, further sensors (**4, 5**) of different construction, such as ionization and/or refraction and/or light transmission sensors and/or temperature sensors (**4**) and/or radiation sensors (**5**), are integrated into the fire responder (**8**), whereby a complex evaluation of the fire event is made possible.

13.
Device following one or more of the claims 9 to 12, **thereby characterized** that one or more of the fire responders (**8**) posses a computer unit (6) (micro controllers or microprocessor) for the reception, for the processing and/or for the transfer of the signals coming from the sensors (**1 to 5**) on a decentralized or central computer unit (central fire responder) (**9**) as well as at least one data memory (**7**).

14.
Device following claim 13, **thereby characterized** that one or more fire responder (**8**) is equipped with an display device (**10**), specifically with a LC-display for the indication of the measured gas concentration.

15.
Device following one or more of the preceding claims, thereby characterized that it is used for the activation of an extinguishing device and/or an alarm system.

Translated from the German by
Dr. Max Roha

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